INDOOR AIR QUALITY ASSESSMENT

Eagle House
Lunenburg Senior Center
Memorial Drive
Lunenburg, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of John Londa, Director of Facilities and Grounds for the Lunenburg School Department, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at the Eagle House, Lunenburg Senior Center, Memorial Drive, Lunenburg, Massachusetts. Concerns about odors in offices and restrooms in the new section of the building prompted the request. On December 23, 2002, a visit was made to this building by Michael Feeney, Director of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, to conduct an indoor air quality assessment.

The Eagle House has two sections. The original building was a three-story, clapboard-sided, wood frame house constructed in 1740. The house was moved to its current location in 1930. The interior of the house was renovated during the years 1988 through 1990. The second section is an addition constructed at the rear of the house in 1998. The 1998 addition contains restrooms, offices, the main function room and kitchen. Windows are openable throughout the building.

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor Model 8551.

Results

The Eagle House has an employee population of five and is visited by approximately 40 to 50 people daily. Tests were taken during normal operations and results appear in Table 1.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were above 800 parts per million of air (ppm) in five out of eight areas surveyed, which is indicative of an overall ventilation problem in the building. Please note that rooms with carbon dioxide levels below 800 ppm were unoccupied, which can greatly reduce carbon dioxide levels, further indicating lack of air exchange.

Two air handling units (AHUs) provide fresh air for the 1998 wing. The office AHU is located in the attic above the offices. This AHU was deactivated during the assessment. The second AHU is located in the attic above the main function room. Each AHU provides conditioned air by a combination of ceiling and wall-mounted air diffusers connected via ductwork. Air returns to the AHU through ceiling or wall-mounted exhaust grilles via ductwork. Each AHU draws fresh air through a PVC pipe mounted in the roof (see Picture 1). A second PVC pipe serves as the exhaust vent for the AHUs.

The ventilation system is controlled by thermostats. Thermostats have a fan switch, which can be set to either “auto” or “on”. Setting the thermostats to “auto” deactivates AHUs at a set temperature. In order to provide continuous supply of fresh air, the thermostat should be set to the “on” position during periods of occupancy in the building.

No functioning mechanical ventilation systems exist in the original building. Each room has a radiator beneath the window that provides heat. The sole source of fresh air is openable windows. With the lack of supply and exhaust ventilation, pollutants that exist in the interior space can build up and lead to indoor air quality and comfort complaints.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last servicing and balancing was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times when the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix I.

Temperature readings ranged from 66^{o} F to 72^{o} F, which were below BEHA recommended comfort guidelines in a number of areas. The BEHA recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Temperature control is often difficult in an old building without the ventilation system functioning (e.g. AHUs deactivated).

The relative humidity ranged from 28 to 34 percent in occupied areas, which was below the BEHA recommended comfort range. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Please note relative humidity in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

The basement along the eastern side of the building showed signs of water penetration. Standing water was noted in the sump pump reservoir. Cement and wooden 2" x 4" frames were moistened (see Picture 2) or had signs of water damage. Efflorescence (i.e. mineral deposits) and peeling paint was observed on the brickwork of basement interior walls (see Picture 3) and in the boiler room. Efflorescence is a characteristic sign of water intrusion. As moisture penetrates and works its way through mortar around brick it leaves behind these characteristic mineral deposits.

Water damage appears to center around a shed-like structure that serves as the exterior entrance into the basement. The roof over this structure forms a joint with the clapboard of the exterior wall of the 1740 building (see Picture 4). The clapboard at this junction appears to be water damaged. The structure has a peaked roof. It does not appear that the edges of either side of the roof were outfitted with gutters or downspouts. As a result, rainwater runs off the roof onto the ground at the base of the building. Over the years, this runoff has created a trench parallel to the base of the wall, which allows rainwater and melting snow to pool against the foundation. In addition, some downspouts around the foundation empty onto accumulated leaves and mulch (see Picture 5). Leaves and mulch hold moisture in contact with the building's foundation.

Shrubbery exists in close proximity to the foundation walls (see Picture 6). The growth of roots against the exterior walls can bring moisture in contact with wall brick and eventually lead to cracks and/or fissures in the foundation below ground level. Over time, this process can undermine the integrity of the building envelope and provide a means of water entry into the building through capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001).

Other Concerns

As described by Mr. Londa, building occupants report that periodic odors were reported in and around the director's office and restroom hallways after the heating system is activated. Since activating the heating system appears to trigger reports of odor, components of the ventilation system servicing the office and surrounding areas were examined. The AHU servicing this general area is located in the attic crawlspace (see Picture 7). Of note is the configuration of the exhaust vent. The AHU is internally heated with natural gas. The combustion products exit the AHU through a series of horizontal PVC pipes that terminate through the roof (see Picture 8). As natural gas is combusted, products of combustion (carbon monoxide, carbon dioxide, particulates, etc.) are generated. Another by-product of combustion is water. The horizontal configuration and lack of exterior insulation would make the PVC pipe exhaust vent prone to accumulation of water by condensation, which requires drainage. In an effort to provide such drainage, a "Y" joint was installed in the PVC pipe exhaust vent as a moisture collector (see Picture 9). A plastic hose connects the lowest point of the "Y" joint to the AHU condensation drainage system. The condensation drainpipe is installed in the air handling section on the AHU near the fan (see Picture 10), which can draw products of combustion from the PVC pipe through the condensation drain system. Therefore, the most likely source of the odors reported by Eagle House staff is products of combustion from the AHU. Since the BEHA visit, Mr. Londa further examined this AHU and has found several other possible breaches that could be sources of products of combustion including the joint between the fan/PVC pipe connection and pinprick holes in the heat exchanger.

Enhancing the accumulation of odors in the eastern section of the new wing is the configuration of the restroom exhaust vents. The hallway outside the restrooms has a fresh air diffuser, which supplies air from the AHU. The restrooms are equipped with ceiling mounted fans, that draw air into a long flexible duct (see Picture 11) connected to a passive (non-motorized) vent in the roof (see Picture 1). Some exhaust ducts have several right-angled bends with at least 12 feet of flexible ductwork between bends. As a rule, each 90^{o} bend in ducting will reduce the draw of air by 50 percent. In this case, the exhaust hose makes roughly three 90^{o} turns (270^{o}). Assuming that the velocity of the draw of air at the metal ductwork at the top of the flexible hose equals 100 percent, the draw of air at the base of the vent is reduced to roughly 12 percent of the draw because of the three 90^{o} bends in the hose. The usual practice employed to make ejection of odors from an interior space is to locate the fan at or near the point of exit in the exterior wall/roof. By locating the fan at the restroom ceiling, the air propelled by the fan rapidly loses velocity due to the length and number of bends in the flexible ductwork. The degradation of exhaust ventilation efficiency prevents the removal of odors from the restrooms and surrounding areas.

As discussed, the process of combustion produces a number of pollutants, depending on the composition of the material. In general, common combustion emissions can include carbon monoxide, carbon dioxide, water vapor and particulates. Of these materials, carbon monoxide can produce immediate, acute health effects upon exposure. The MDPH established a correction action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm taken 20 minutes after resurfacing within the rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The US Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide in outdoor air. Carbon monoxide levels in outdoor air must be maintained below 9 ppm over a twenty-four hour period in order to meet this standard. These NAAQS are used by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) as measures for assessing indoor air quality in buildings (ASHRAE, 1989). No carbon monoxide levels measured in the Eagle House exceeded the MDPH ice rink correction levels or NAAQS.

The building also shows signs of rodent infestation. Mouse droppings were noted behind the cabinets in the old kitchen (see Picture 12). Rodent infestation can result in indoor air quality related symptoms due to materials in their wastes. Mouse urine is known to contain a protein that is a known sensitizer (US EPA, 1992). A sensitizer is a material that can produce symptoms in exposed individuals (e.g., running nose or skin rashes). A three-step approach is necessary to eliminate rodent infestation:

- Removal of the rodents;
- Cleaning of waste products from the interior of the building; and
- Reduction/elimination of pathways/food sources that are attracting rodents.

To eliminate exposure to allergens, rodents must be removed from the building. Please note that removal, even after cleaning, may not provide immediate relief since allergens can exist in the interior for several months after rodents are eliminated (Burge, H.A., 1995). A combination of cleaning and an increase in ventilation and filtration should serve to reduce rodent associated allergens once infestation is eliminated.

Finally, AHUs are equipped with filters that strain particulates from airflow. Filters installed in AHUs appear to be of a type that will provide minimal filtration of respirable particles. In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates (Thornburg, D., 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the unit by increased resistance (called pressure drop). Prior to any increase of filtration, each AHU should be evaluated by a ventilation engineer to ascertain whether they can maintain function with more efficient filters. The age and condition of AHUs may preclude any attempt to increase filter efficiency.

Conclusions/Recommendations

In order to address the conditions listed, the recommendations made to improve indoor air quality in the building are divided into short-term and long-term corrective measures. The

short-term recommendations can be implemented as soon as practicable. **Long-term** solution measures are more complex and will require planning and resources to adequately address the overall indoor air quality concerns.

Short Term Recommendations

1. Continue with plans to separate the moisture drain from the base of the AHU.
2. Continue with plans to repair breach in exhaust fan/PVC pipe system.
3. Set thermostats to the fan "on" position to operate the ventilation system continuously.
4. Ventilation industrial standards recommend that mechanical ventilation systems be balanced every five years (SMACNA, 1994). Consult a ventilation engineer concerning re-balancing of the ventilation systems.
5. Examine the feasibility of increasing the efficiency of AHU filters. Prior to any increase of filtration, each piece of air handling equipment should be evaluated by a ventilation engineer as to whether it can maintain function with more efficient filters.
6. To prevent moisture penetration into the basement, the following actions should be considered:
    a) Install gutters on the edge of the roof covering the basement exterior entrance;
    b) Remove mulch from areas near foundation;
    c) Move foliage to no less than five feet from the foundation;
    d) Improve the grading of the ground away from the foundation at a rate of 6 inches per every 10 feet (Lstiburek, J. & Brennan, T., 2001);
    e) Install a water impermeable layer on ground surface (clay cap) to prevent water saturation of ground near foundation (Lstiburek, J. & Brennan, T., 2001).

7. Consider replacing the water-damaged 2" x 4"s in the basement. Remove this material in a manner consistent with US EPA recommendations for mold remediation (US EPA, 2001).

8. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

9. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

10. It is highly recommended that the principles of integrated pest management (IPM) be used to rid the building of pests. A copy of the IPM recommendations can be obtained from the Massachusetts Department of Food and Agriculture (MDFA) at the following website: http://www.state.ma.us/dfa/pesticides/publications/IPM_kit_for_bldg_mgrs.pdf. Activities that can be used to eliminate pest infestation may include the following:

    a) Rinse out recycled food containers. Seal recycled containers in a tight fitting lid to prevent rodent access;
    b) Remove non-food items that rodents are consuming;
    c) Stored foods in tight fitting containers;
    d) Avoid eating at workstations. In areas were food is consumed, periodic vacuuming to remove crumbs are recommended;

e) Regularly clean crumbs and other food residues from toasters, toaster ovens, microwave ovens coffee pots and other food preparation equipment;

f) Holes as small as ¼" are enough space for rodents to enter an area. Examine each room and the exterior walls of the building for means of rodent egress and seal . If doors do not seal at the bottom, install a weather strip as a barrier to rodents;

g) Reduce harborages (e.g. cardboard boxes) where rodents may reside (MDFA, 1996).

Long Term Recommendations

1. Consideration installing exhaust fans for restrooms at the duct termini at the roof to maximize draw. Examine the feasibility of decreasing the number of bends in flexible ducts.

References

ASHRAE. 1992. Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 52.1-1992.

ASHRAE. 1989. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1989.

BOCA. 1993. The BOCA National Mechanical Code-1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL. M-308.1

Burge, H.A. 1995. *Bioaerosols*. Lewis Publishing Company, Boca Raton, FL.

Lstiburek, J. & Brennan, T. 2001. Read This Before You Design, Build or Renovate. Building Science Corporation, Westford, MA. U.S. Department of Housing and Urban Development, Region I, Boston, MA

MDFA. 1996. Integrated Pest Management Kit for Building Managers. Massachusetts Department of Food and Agriculture, Pesticide Bureau, Boston, MA.

MDPH. 1997. Requirements to Maintain Air Quality in Indoor Skating Rinks (State Sanitary Code, Chapter XI). 105 CMR 675.000. Massachusetts Department of Public Health, Boston, MA.

MEHRC. 1997. Indoor Air Quality for HVAC Operators & Contractors Workbook. MidAtlantic Environmental Hygiene Resource Center, Philadelphia, PA.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R. 1910.1000 Table Z-1-A.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.

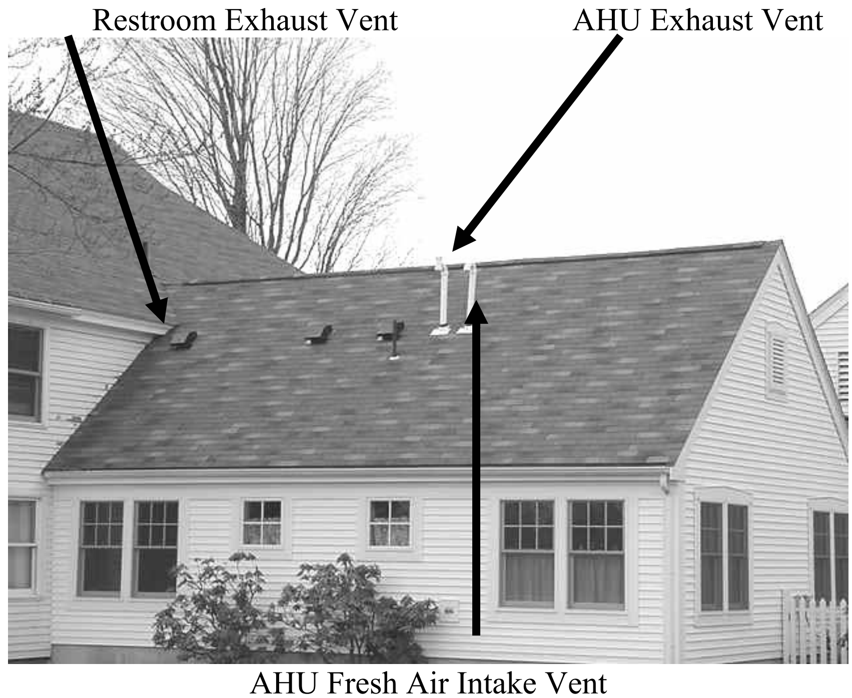
SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

Thornburg, D. 2000. Filter Selection: a Standard Solution. *Engineering Systems* 17:6 pp. 74-80.

US EPA. 2001. Mold Remediation in Schools and Commercial Buildings. US Environmental Protection Agency, Office of Air and Radiation, Indoor Environments Division, Washington, D.C. EPA 402-K-01-001. March 2001. http://www.epa.gov/iaq/molds/mold_remediation.html

US EPA. 1992. Indoor Biological Pollutants. US Environmental Protection Agency, Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Research Triangle Park, NC. ECAO-R-0315. January 1992.

Picture 1

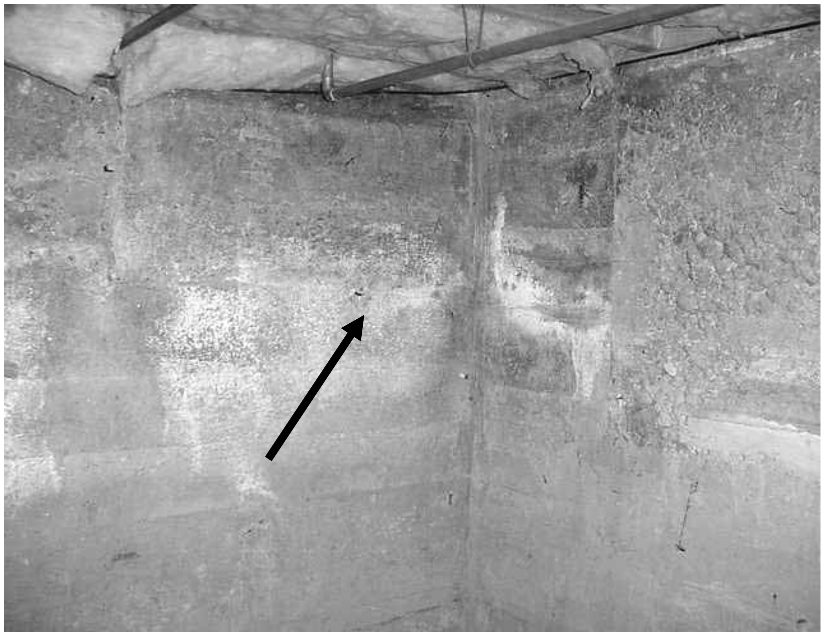


PVC Pipes Mounted in the Roof Serving As Supply and Exhaust Vent

Picture 2

Moistened 2” X 4” Frame in Basement

Picture 3



Efflorescence (I.E. Mineral Deposits) Was Observed On the Brickwork on the Interior Walls of the Basement

Picture 4

Shed-Like Structure That Serves As the Exterior Entrance into the Basement, Note Lack of Gutter/Downspout System

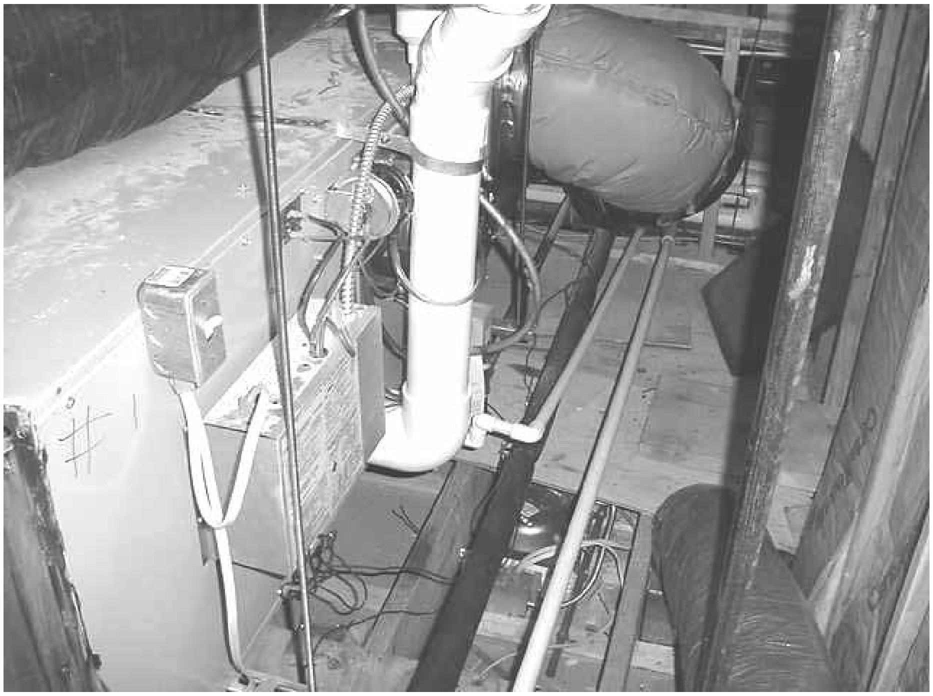
Picture 5

Downspouts around the Foundation Empty onto Accumulated Leaves and Mulch

Picture 6

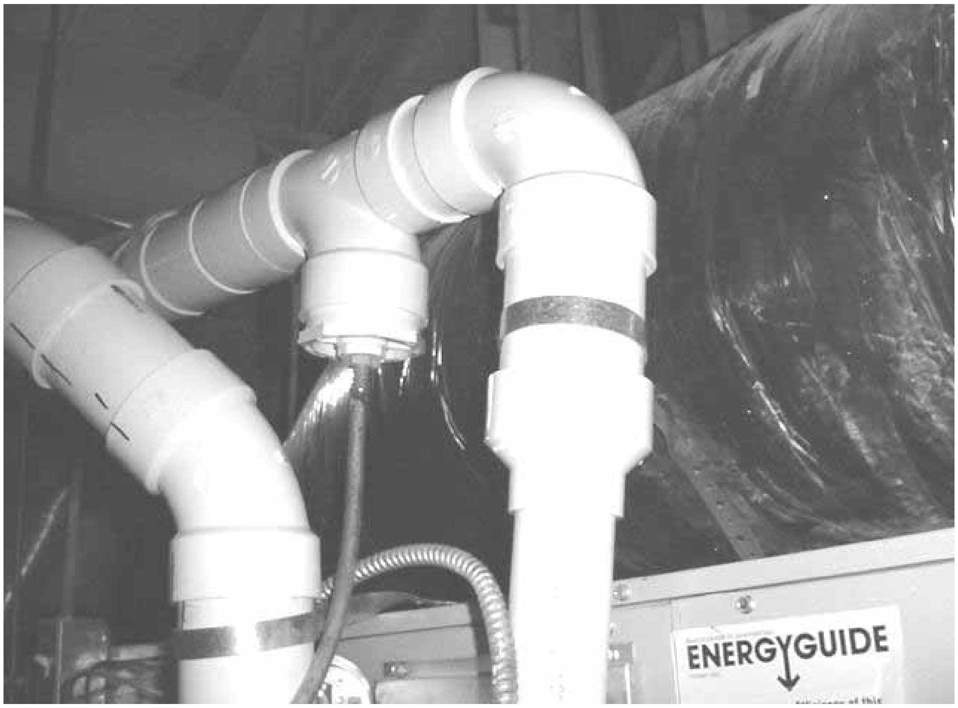
Shrubbery Exists in Close Proximity to the Foundation Walls

Picture 7



AHU Servicing This General Area Is Located In the Attic Crawlspace

Picture 8



The Combustion Products Exit the AHU through A Series of Horizontal PVC Pipes That Terminate through the Roof

Picture 9

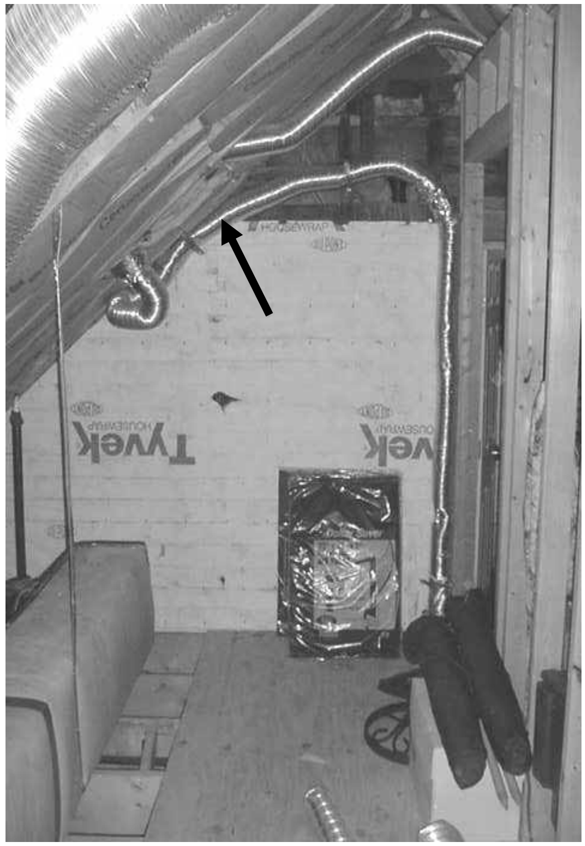
“Y” Joint Was Installed In the PVC Pipe Exhaust Vent as a Moisture Collector

Picture 10

Condensation Drain

This Condensation Drainpipe Is Installed Into the Air Handling Section of the AHU

Picture 11



Restrooms Are Equipped With Ceiling Mounted Fans, Which Expels Air into A Long Flexible Duct

Picture 12

Mouse Droppings behind the Cabinets in the Old Kitchen

TABLE 1

Indoor Air Test Results – Eagle House Senior Center – Lunenburg, Massachusetts December 23, 2002

Location	Carbon Dioxide *ppm	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	310	39	33					
Main Office	785	66	32	3	Y	Y	Y	Exhaust off, door open Supply off
Main Meeting Room	1168	71	34	22	Y	N	N	Hall – AC Door open
Kitchen (Old Building)	1429	72	33	0	N	N	N	Mouse droppings Door open
RR Hallway	739	69	26	0	Y	Y	Y	Plants Door open
Kitchen (New Building)	903	69	30	2	Y	Y	Y	Kitchen hood off Door open
Main Meeting Room (New Building)	890	69	29	2	Y	Y	Y	Door open
Computer Room	777	68	21	0	Y	N	N	Door open
Main Hallway (Old Building)	920	67	29	0	Y	N	N	

*** ppm = parts per million parts of air**

CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%